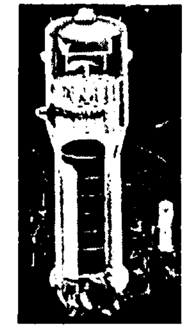
**Session 4**
**February 28, 2001**

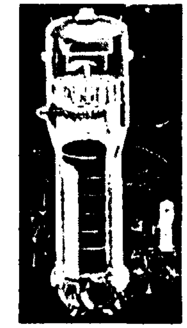
EPRI



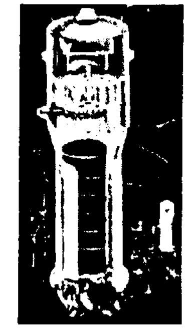
# Steam Generator Integrity Assessment Guidelines

Kevin Sweeney
Arizona Public Service
February 28, 2001

# Agenda

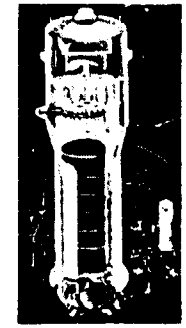


- Guideline Objective
- Background
- Guideline Format
- Key Terms in Integrity Assessment
- Tools
- Summary



# SG Integrity Assessment Guidelines

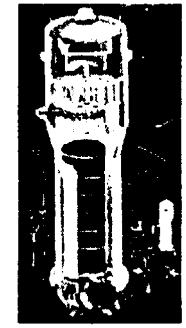
- Objective
  - Develop industry guidance for performing Condition Monitoring (CM) and Operational Assessments (OA)
    - Required per NEI 97-06
    - Should function with other Integrity Element Guidelines
- Challenge
    - No previous industry or regulatory standard for tube integrity assessment
    - Sufficiently flexible to address all forms of SG degradation and several assessment strategies
- Purpose
    - Demonstrate compliance with performance criteria



# Guideline Background

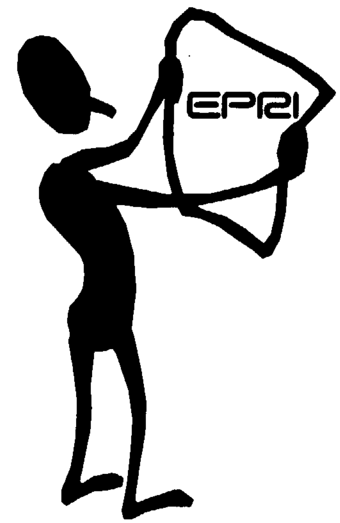
- Significant industry effort to develop guidance
  - Working Group established 2/97
    - Several significant draft revisions
  - Early feedback
    - Complicated/confusing
    - Industry and regulatory criteria evolving
  - Final draft issued 10/98
    - Comments received from utilities and vendors
      - Over 200 comments resolved
  - Document issued March 2000
  - Changed to Integrity Element in NEI 97-06 Rev 1

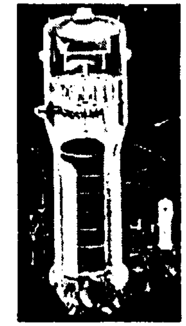
EPRI



# Guideline Format

- Section 1 - Introduction
- Section 2 - Fundamentals of SG Tube Integrity Assessment
- Section 3 - Degradation Assessment
- Section 4 - NDE Techniques
- Section 5 - Structural Integrity Assessment Limits
- Section 6 - Degradation Growth Rate
- Section 7 - Allowable Accident Induced Tube Leakage
- Section 8 - Condition Monitoring
- Section 9 - Operational Assessment
- Section 10 - Operational Leakage
- Section 11 - Documentation and Reporting Requirements
- Section 12 - Glossary
- Section 13 - List of Abbreviations and Acronyms
- Section 14 - References



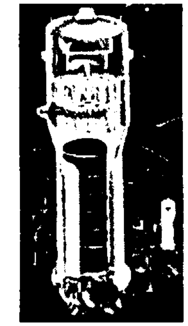


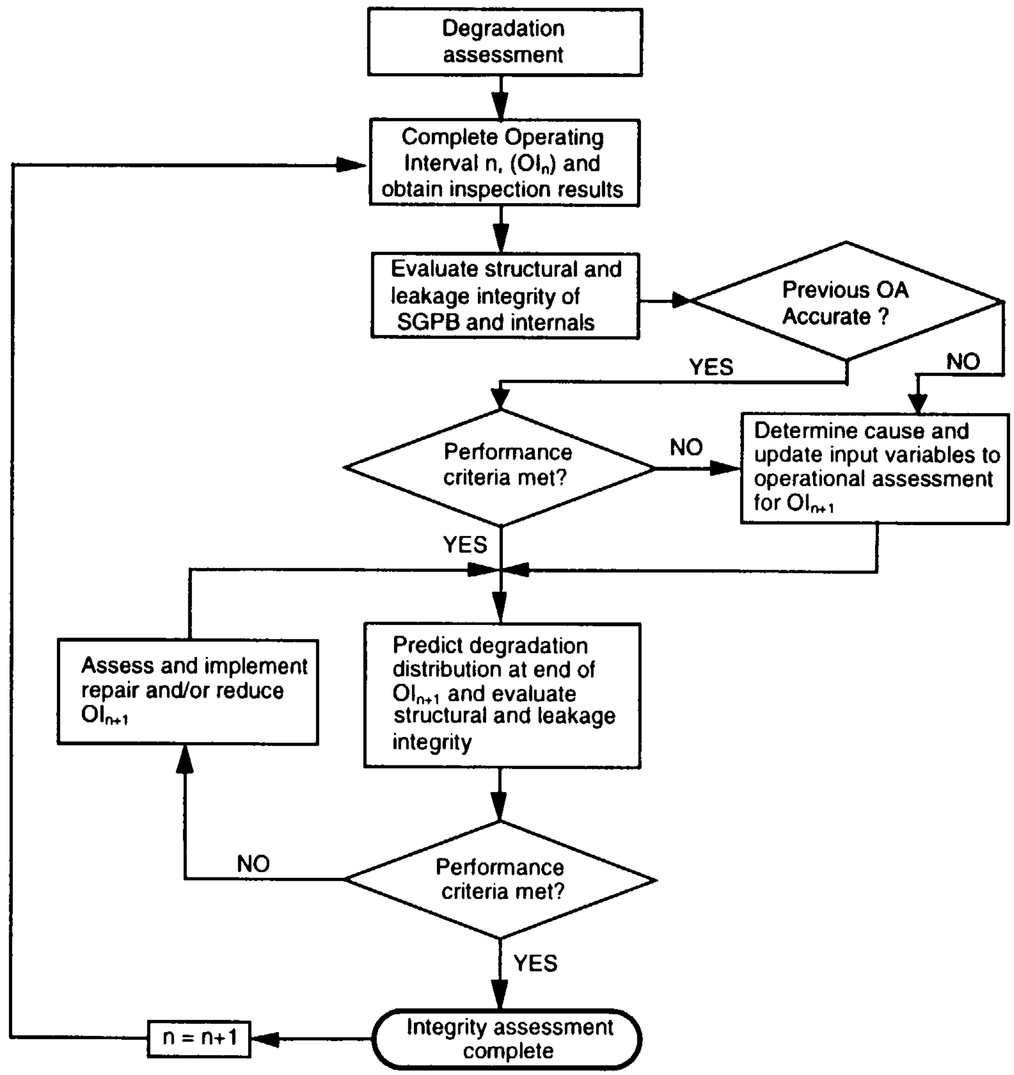
# Guideline Format (cont)

- Appendices
  - Appendix A - Example of Degradation Assessment and Inspection Requirements
  - Appendix B - Sample Checklist for Pre-Outage Assessment
  - Appendix C - Calculation of Steam Generator Tube Leakage
  - Appendix D - Summary of SG Integrity Assessment - Example Form
  - Appendix E - Example of OA Limit Determination for Tube Wall Thinning
  - Appendix F - Illustration of Voltage-based Simplified Statistical and Monte Carlo Methods
  - Appendix G - Monte Carlo Analysis
  - Appendix H - Method for Combining Data Sets
  - Appendix I - POPCD Example and POD Procedures
  - Appendix J - Risk Informed Inspections
  - Appendix K - Radiological Assessment Guidelines
  - Appendix L - SGDSM On-Line Data Base Use
  - Appendix M - Industry White Papers Defining Burst and Pressure Loading for Structural Integrity Assessment

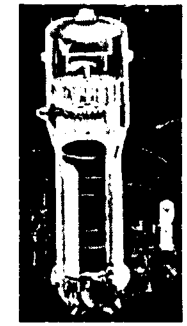
EPRI

# Integrity Assessment Process



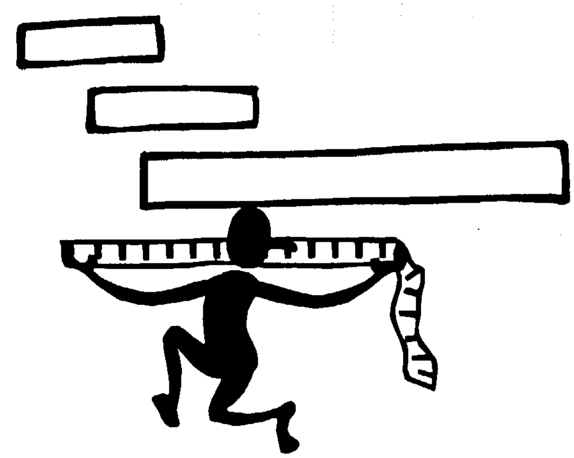


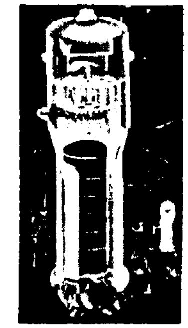
EPRI



# Terms - Performance Criteria

- NEI 97-06 Performance Criteria designed to provide reasonable assurance the SG RCPB capable of fulfilling safety function
- Performance Criteria should also be:
  - Measurable
    - Program effectiveness
  - Achievable
    - Should not be an issue to safe, well run programs
  - Lead to corrective actions, if required
    - Flag problem areas
    - Self Assessment

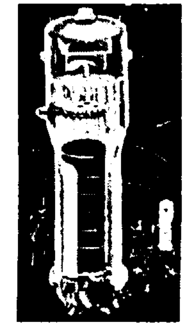




# Performance Criteria - NEI 97-06

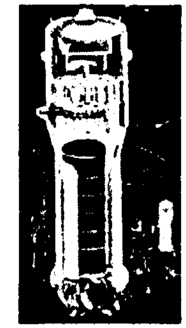
- NEI 97-06 specifies three (3) performance criteria
  - Structural Integrity
    - Protection against burst during accidents which tube integrity is assumed
      - Defined Margins of Safety (3NODP, $1.4P_{acc}$)
  - Accident Induce Leakage Integrity
    - Maintain licensing basis assumptions for accidents other than SGTR
      - Dose consequences
      - Not to exceed 1 gpm per SG without NRC approval
  - Operational Leakage
    - Based on Industry Experience
      - Protection against spontaneous rupture

NEI



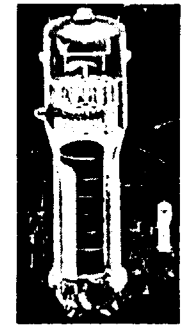
# Terms - CM and OA

- Condition Monitoring
  - Assessment (***Monitoring***) of the "as-found" ***condition*** of the steam generator relative to performance criteria
    - Determines if performance criteria were satisfied for the just completed operating cycle
      - Failure to satisfy criteria requires reporting to NRC
- Operational Assessment
  - Assessment differs from condition monitoring as it is "forward looking"
    - Involves evaluating/modeling Steam Generator Program
      - Inspection, repair and operation processes
    - Provide reasonable assurance that performance criteria will be satisfied for the next operating period

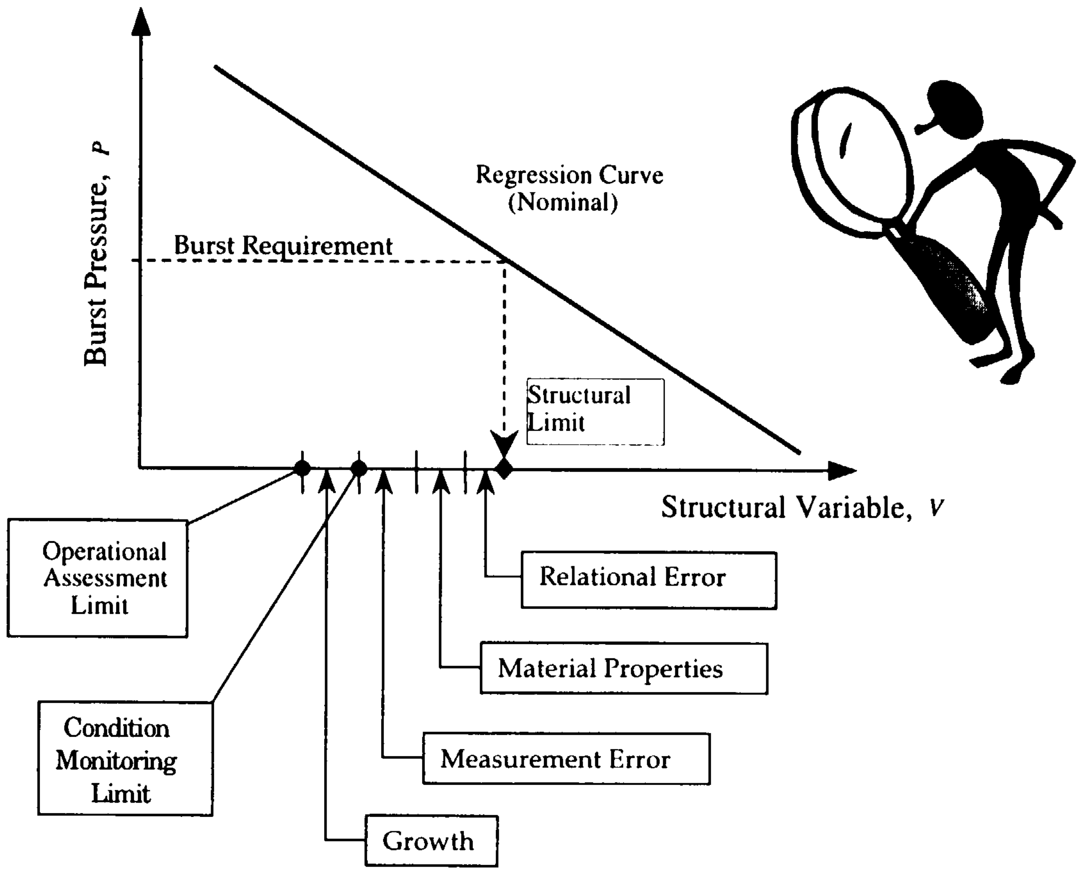


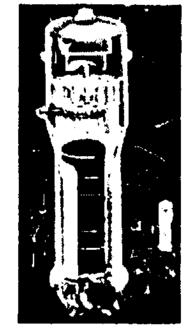
# Terms - Assessment Strategies

- Integrity guideline provides computational hierarchy of analytical techniques to verify tube structural and leakage integrity
  - Arithmetic
  - Simplified Statistical
  - Monte Carlo
- Strategies use similar structure to assess EOC tube integrity
  - Burst Pressure = f {BOC, Growth, NDE, Materials)
    - Each strategy is dependent on the availability and accuracy of input data



# Terms - Tube Integrity Elements

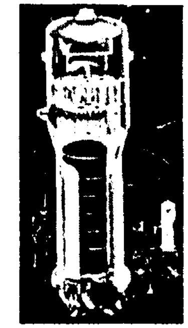




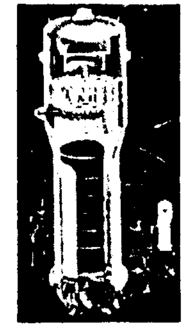
# Tools - Degradation Assessment

- EPRI SG Integrity Assessment Guideline
  - Chapter 3 - Methodology
  - Appendix A - Checklist
- EPRI PWR SG Examination Guideline
  - Section 5.2
- EPRI Steam Generator Database
  - Electronic database
    - Industry inspection and repair results
- Industry Participation
  - EPRI, NEI, INPO, Owners Groups, NSSS vendors
  - Workshops
- EPRI R&D Efforts

# Tools - NDE Inputs

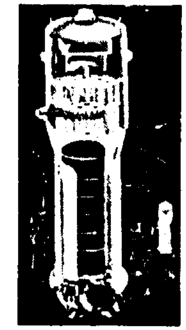


- EPRI PWR SG Examination Guideline
  - Analyst and Technique Qualification
    - Consistent application
    - POD and NDE uncertainty - key inputs
  - Site Specific Performance Demonstration
- EPRI SG Integrity Assessment Guideline
  - Chapter 4
- ERPI Steam Generator Databases
  - Reference to tube pull and in situ data
- EPRI NDE Center
  - Utility technical support and product qualification



# Tools - Degradation Growth

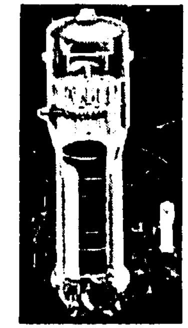
- EPRI SG Integrity Assessment Guidelines
  - Chapter 6
- EPRI - Degradation Statistics & Predictions
  - Methodologies
  - Effects of Thot, material differences
  - Laboratory results
- EPRI Steam Generator Database
  - Defect data, operating conditions, tube pull results



# Tools - Structural and Repair Limits

- EPRI SG Integrity Assessment Guideline
  - Chapter 5
- EPRI Flaw Handbook
- EPRI ARC Topical Reports
  - Axial ODSCC @ TSP, Circumferential Indications
  - ODSCC Database
- EPRI R&D Efforts
  - Burst Correlation Data
  - Pressurization Ramp Rate
- EPRI In Situ Test Guidelines

EPRI



# Summary

- Guideline meets industry objectives as initial standard for tube integrity assessment
- Industry expects guideline to evolve as experience dictates
  - Similar to experience with Examination GL and Primary to Secondary Leakage GL
- Issues
  - Incorporate Lessons Learned
  - Continue industry education via meetings, self assessment and workshops
  - Develop/improve industry tools
  - Formation of Ad Hoc Tube Integrity Committee

# NRC Perspective on Several SG Tube Integrity Issues

Emmett L. Murphy, (301) 415-2710
Office of Nuclear Reactor Regulation, NRC

Steam Generator Workshop
Bethesda, Maryland
February 27-28, 2000

## Staff Perspective/Detailed Industry Guideline Documents

- Have contributed significantly to improved SG tube integrity performance.

- Consideration of these guidelines is essential to ensuring SG tube integrity performance criteria are met.

- Have no regulatory standing; staff has no plans to endorse.

- These guidelines still contain numerous shortcomings.

- Adherence to these guidelines may not be sufficient.

- Actions beyond these guidelines may be necessary to ensure performance criteria are met and to be in compliance with 10 CFR 50, Appendix B, Criterion 16.

- The industry should continue to work with the staff to identify and discuss existing shortcomings and needed improvements.

# Tube Integrity Assessment Issues

- Treatment of Uncertainties
- NDE flaw detection and sizing performance
  - in situ screening criteria
  - operational assessment
- Fractional flaw methodology
- Definition of limiting accident
- Benchmarking of operational assessments
- Interpretation of in situ pressure test results
- Pressurization rate issue (Majumdar)
- Need for higher capacity in situ pressure test systems (Majumdar)

# Treatment of Uncertainties

- NEI 97-06 provides general guidance.

- Tube integrity assessment guidelines:

  - Structural limits are set such that a flaw evaluated to be at the limits satisfies the structural performance criteria with probability of 0.9 evaluated at a 50% confidence level.

  - Probability of burst of one or more tubes (for the population of degraded tubes) < 0.1 at applicable performance criteria.

- These values are less than those proposed by the staff in DG-1074 and approved for a recent ARC application:

  - .95/.95 for operational assessment
  - .95/.50 for condition monitoring

# NDE Flaw Detection and Sizing Performance

- Detection and sizing performance given in EPRI ETSS sheets may be inappropriate for use in defining in situ test screening criteria and for use in tube integrity assessments.
  - Of particular concern for cracks
- Detection and sizing performance should ideally be based on a performance demonstration which:
  - quantifies performance of the total NDE system (technique and personnel) in blind test relative to ground truth
  - includes a statistically significant number of flawed tube specimens over the full range of flaw sizes of interest
  - utilizes flawed tube specimens representative of conditions in the field in terms of flaw morphology, tube and support geometry, flaw signal response, noise, and signal to noise.

## NDE Flaw Detection and Sizing Performance (Cont)

- For flaw mechanisms for which such a performance demo is not available:
  - A sample of affected tubes should be in situ tested. Field sizing measurements should only be used to help prioritize tubes for testing.
  - A cautious, conservative approach should be taken during operational assessments when applying POD and flaw sizing error assumptions. These assumptions should be assessed against actual inspection and/or in situ pressure test results for consistency.
  - Initiate rigorous performance demo.

## Interpretation of In Situ Pressure Test Results

- In-situ testing may fail to reach target pressure (e.g., 3 delta P) due to leakage in excess of test system capacity.

- Guidelines permit engineering assessment to assess burst or leakage integrity relative to applicable performance criteria.

  - These guidelines should be upgraded to ensure an objective assessment (i.e., an assessment which is uniquely consistent with all the available evidence).

- The engineering assessment should account for the uncertainties in the NDE flaw size measurement and the models used to assess local and gross ligament tearing, burst, and leak rate. Leak rates exhibit a high degree of scatter for a given through wall crack length.

# Fractional Flaw Methodology

The fractional flaw method is based on the assumption that for each flaw found by inspection, there are flaws of the same size which were not detected by inspection (i.e., 1/POD - 1).

- Approved by NRC for voltage-based ODSCC alternate repair criteria ARC at support plate intersections and PWSCC ARC at dented support plate intersections.
  - Licensees currently assuming a constant POD of 0.6 for these applications.
- An operational assessment for IP-2 utilized the fractional flaw methodology in conjunction with a POD assumption which varied as a function of crack size.

## Fractional Flaw Methodology (Continued)

- The staff's review found that use of variable POD in conjunction with the fractional flaw method led to results which were insensitive to the size of the indications found by inspection.
  - The staff considered this finding unrealistic.
- The industry should assess this issue and revise the guidelines as needed.

# Limiting Accident

- The tube integrity assessment guidelines and the NEI steam generator generic change package define "limiting accident" to be an accident that from a structural standpoint results in the largest pressure differential across the steam generator tubes, normally a main steam line or feed water line break.

- The definition should more properly state that

  - from a structural standpoint, "limiting accident" means an accident which in conjunction with a safe shutdown earthquake results in the minimum margin against burst (i.e., gross failure).

# Benchmarking of Operational Assessments

- Should be performed as part of each operational assessment to confirm that analysis methodology is conservative and to ensure that NDE detection and sizing uncertainties and growth rate uncertainties have been adequately accounted for.

- Should consider both best estimate and bounding predictions from operational assessments.

- Should avoid taking credit for NDE procedural improvements implemented during current inspection unless supported by quantitative data concerning the expected degree of detection or sizing performance (ideally by performance demonstration).

## Pressurization Rate Effect

- Pressure tests performed on EDM notched specimens intended to replicate ODSCC flaw at ANO-2 which leaked during in situ testing.

- Ligament tearing and burst pressure results varied as a function of the pressurization rate (from essentially quasi-static to 2000psi/sec).

- Argonne (ANL) data also indicates a pressurization rate effect.

- Potential implications:

  - empirical burst models, if high pressurization rates used
  - analytical ligament tearing and burst models
  - procedures for laboratory and in situ burst testing

## Pressurization Rate Effect (Continued)

- Preliminary industry assessment:

  - Rate effect limited to planar cracks greater than 90%.
  - Time dependancy effect is essentially complete within 1 minute.
  - No impact on empirical burst pressure correlations.
  - Analytical models are conservative.
  - Test procedures should be revised.

- NRC staff is also investigating this issue and will review the industry's findings when completed.

- In meantime, the staff has not accepted new ARC applications involving use of empirical burst correlations for part TW cracks.

- Recent revisions to the in situ test procedure guidelines are a significant improvement, reducing the potential for missing time dependant ligament behavior.

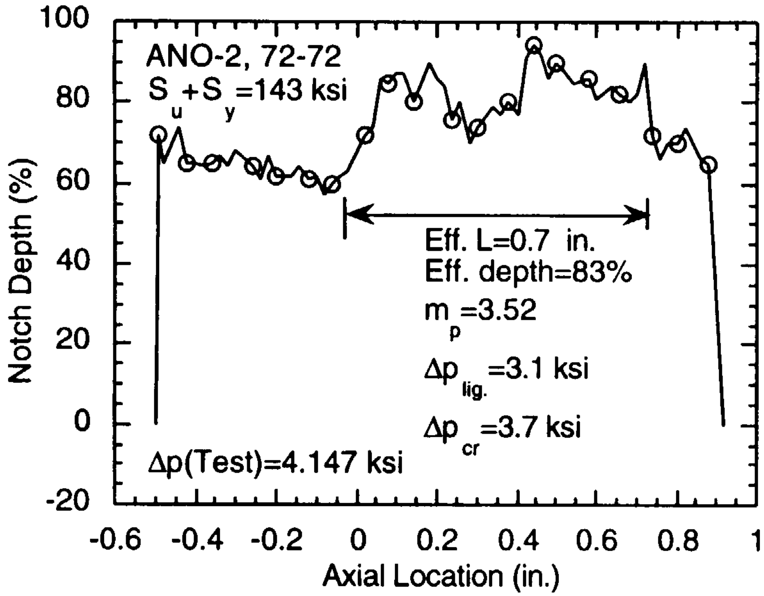
# Pressurization Rate Effect on Burst Pressure/ Pumping Requirements for $3\Delta p_{NO}$ Tests

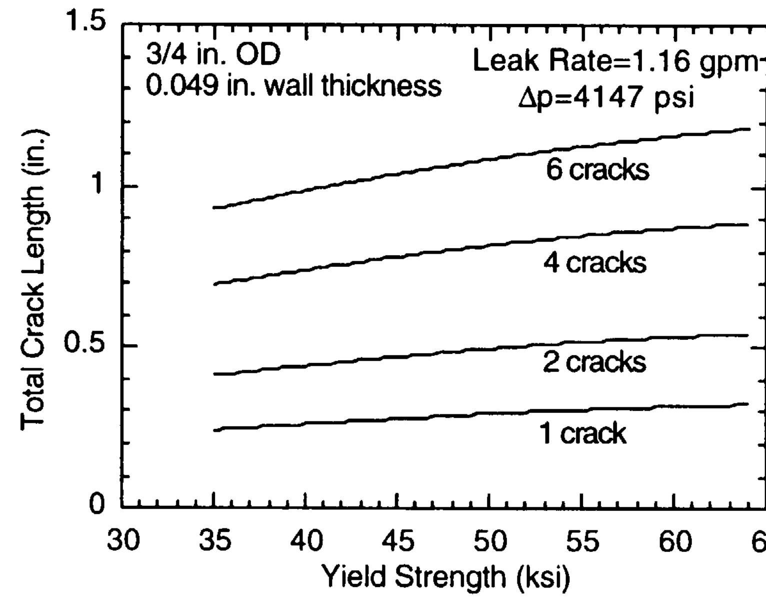
by

Saurin Majumdar
Energy Technology Division
Argonne National Laboratory

Presented at the Steam Generator Workshop in Bethesda on Feb. 27-28, 2001.

# Comments on Westinghouse Tests on ANO-2 Tubes




- Type 14 specimen design assumed EC had overcalled depth in 72-72
- Aternative interpretation suggested by leakage and burst analyses is that there may have been 2-4 cracks separated by axial or circumferential ligaments
- Planar notch (Type 14) w/o ligament is not a good simulator of 72-72 crack

# Pressurization Rate Effect on Ligament Rupture (Burst) Pressure of Type 14 Specimen

- Slow rate tests resulted in ligament rupture but no unstable burst
  - Post-ligament-tearing tests showed lower unstable burst pressures
  - Specimens would have burst unstably with higher capacity pump
- Fast rate tests (using bladder and foil) resulted in unstable burst
  - Unstable burst occurred immediately after ligament rupture
- Rate effect (average 30% increase in ligament rupture (burst) pressure from quasi-static to 2 ksi/s) was established from the cumulative distribution of ligament rupture (burst) pressures
- Measured notch profiles significantly different from designed profile

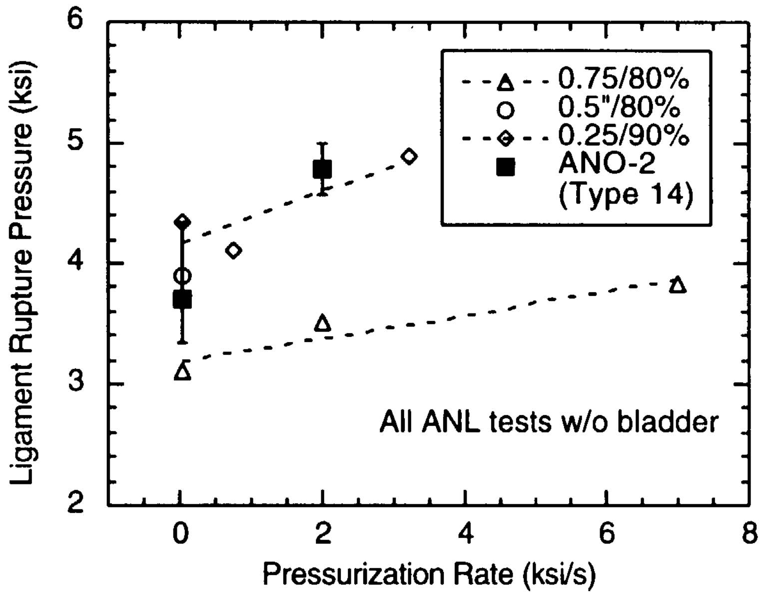
# Potential Sources for Rate Effect in Type 14 Specimen

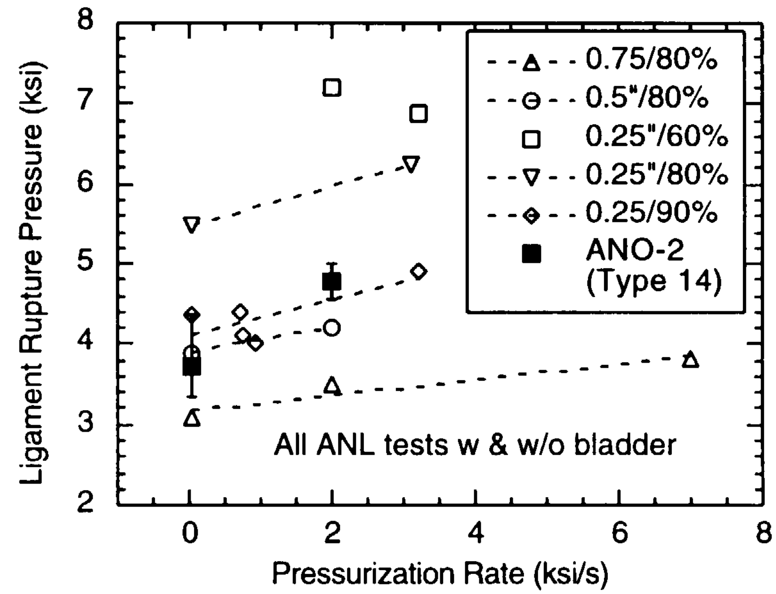
- Bladder and foil may have artificially increased burst pressures of fast rate tests.
  - General consensus is that bladder and foil effect, if any, is small.
- Systematic differences in notch profiles between slow and fast rate test specimens may have skewed the results.
  - Analysis shows that these differences may account for some of the observed “rate effect” but not all of it.
- There is a “true” residual pressurization rate effect on radial ligament rupture pressure that cannot be explained by artifacts.

# Conclusions from ANL Rectangular Notch Tests

- Tests on 0.25"/90% and 0.75"/80% notches w/o bladder showed a pressurization rate effect on radial ligament rupture pressure above 1ksi/s.
  - Rupture pressure increases by ≈ 10% from quasi-static to 2 ksi/s.
- Tests on 0.5"/60% notches showed no effect of bladder (1/8" Tygon) on unstable burst pressure.
- No difference in unstable burst pressures of 0.5"/100% notches between tests using bladder with foil (0.005" brass) and bladder w/o foil.

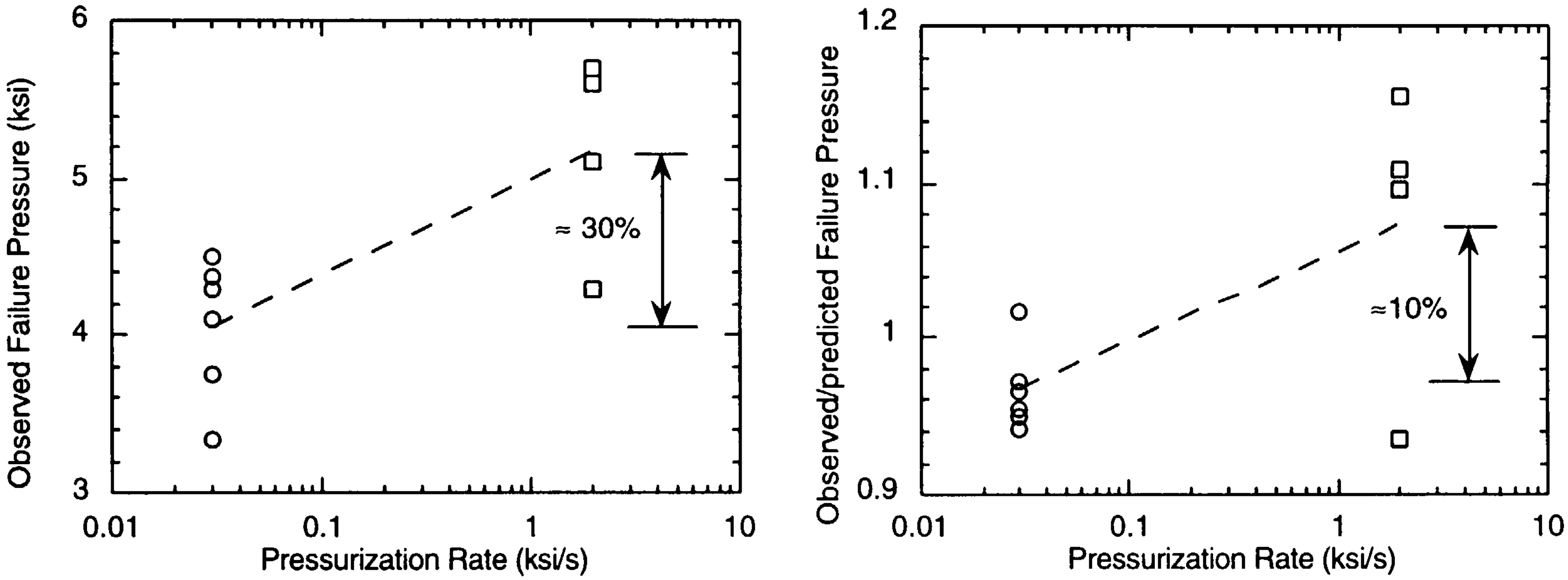
# Pressurization Rate Effect on Ligament Rupture Pressure of EDM notches – Rectangular vs. Type 14




- Increase in pressurization rate from quasi-static to 2 ksi/s increases ligament rupture pressure in deep (≥ 80%), rectangular flaws by ≈ 10% and apparent ligament rupture pressure in Type 14 flaws by ≈ 30%.

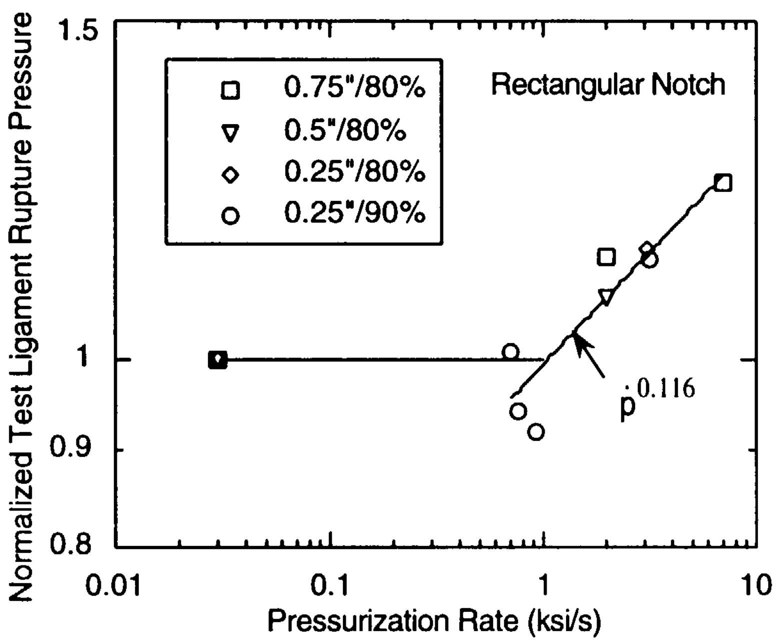
# Apparent and "True" Rate Effect in Type 14 Specimens

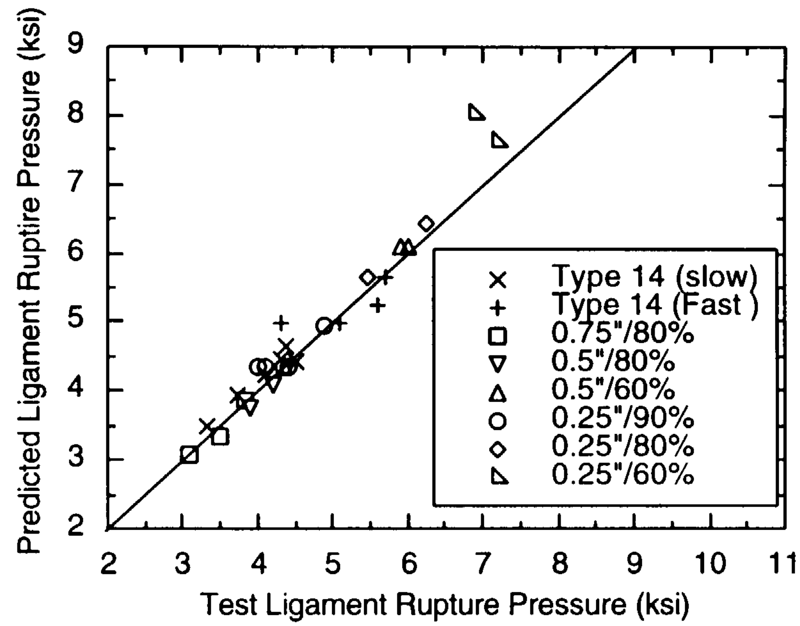



- Variation of ligament rupture pressure due to variation in notch geometry can be normalized out by plotting observed/predicted ligament rupture pressure (calculated with actual notch geometry).

- The "true" rate effect (from quasi-static to 2 ksi/s) on ligament rupture pressure is close to that observed for ANL rectangular notches (≈ 10%).

# Accounting for Rate Effect in Rectangular and Type 14 Notch Specimens

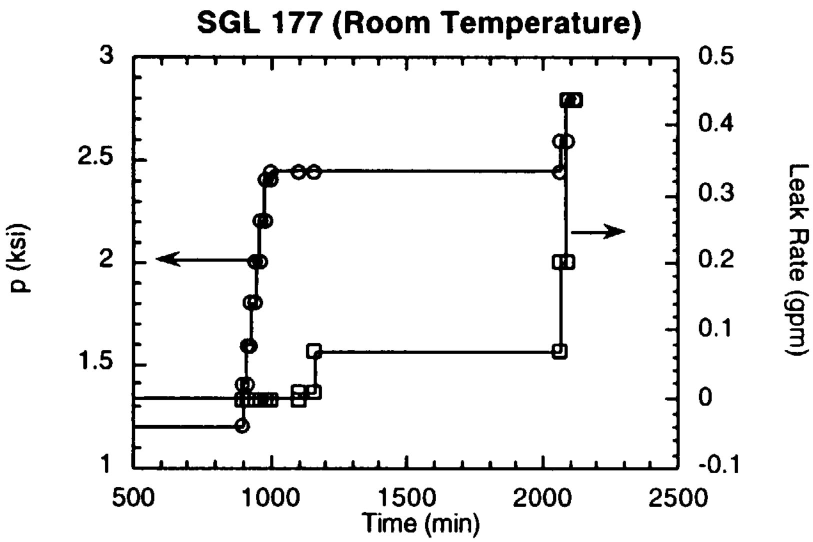


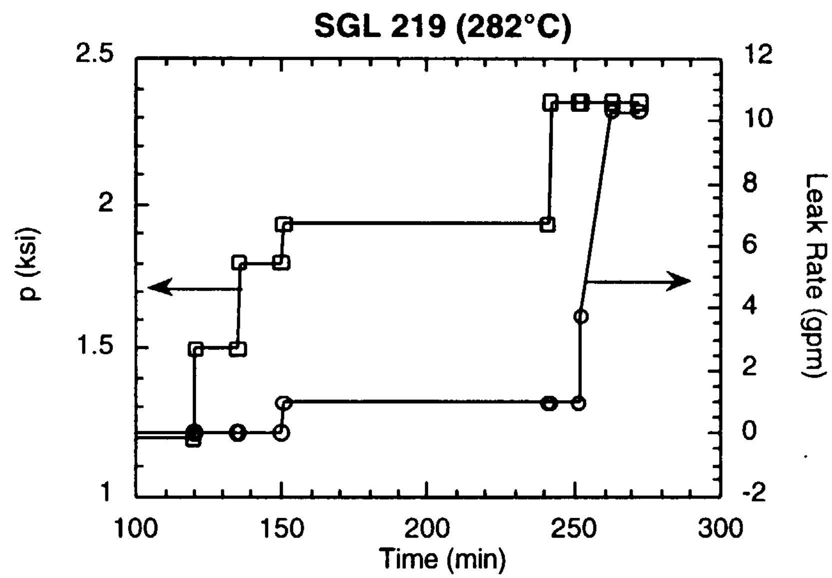




- All deep rectangular and Type 14 notch radial ligament rupture pressure data can be predicted by assuming rate effect to kick in above 1 ksi/s with a pressure rate exponent of 0.116.

- More tests are needed to verify the assumption.

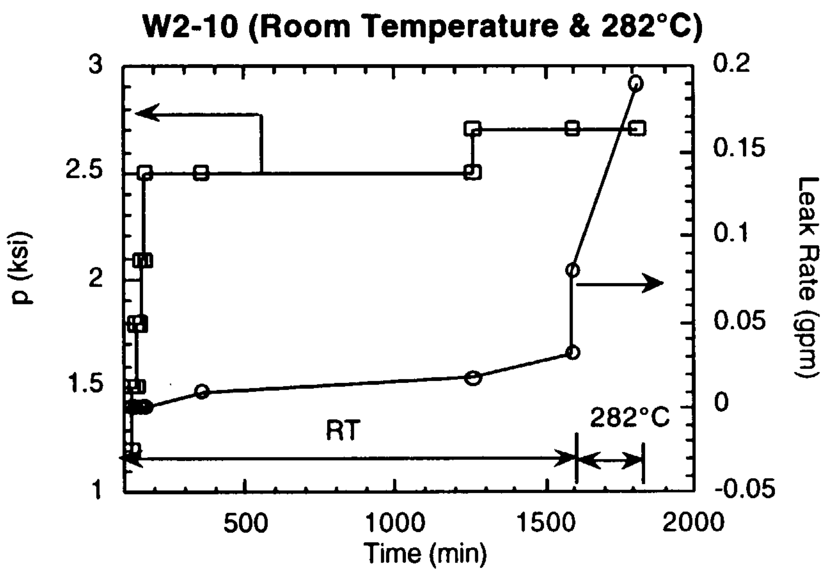
# Time-Dependent Effects in Pressure Tests on SCC Specimens (Annealed & Sensitized) at Room Temperature and 282°C

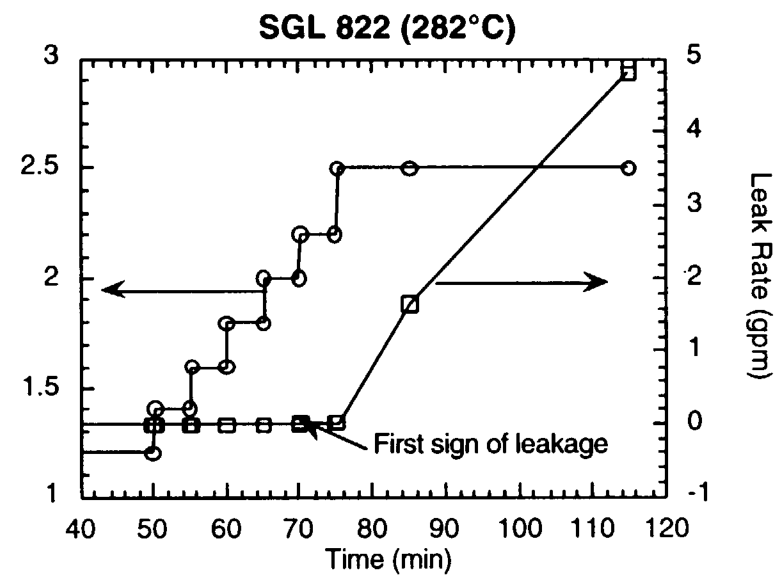



- Sudden and/or gradual increase in leak rate under constant pressure hold
- Not all specimens show time dependent leak rate at constant pressure hold.

# Pressure Tests on Specimens w/o Annealing Treatment




- Both the Westinghouse (doped steam) and ANL (sensitized w/o high temperature annealing) specimens leaked air at 40 psi and showed time dependent increase of leak rate under constant pressure hold during tests.

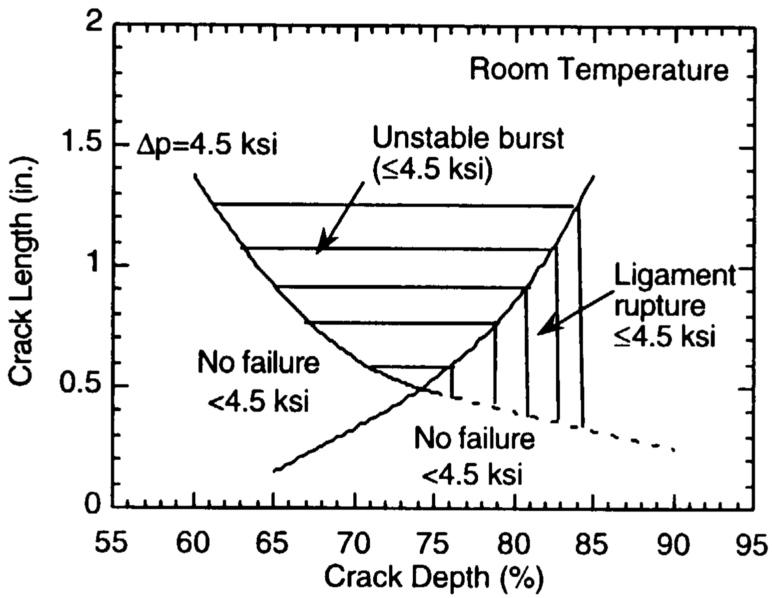
- Time-dependent ligament rupture at constant pressure suggests rate-dependent ligament rupture pressure for deeply cracked SCC specimen.

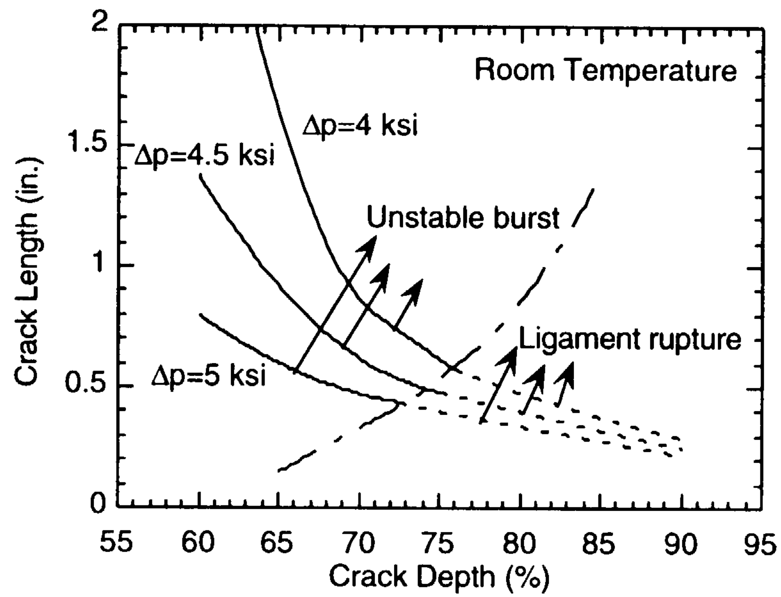
# Rate Effect on Unstable Burst Pressure

- Pressure-rate-independence of voltage vs. burst pressure correlation supplied by Westinghouse is at best indirect evidence for rate independence, because data plotted have been normalized for voltage calibration and flow stress variation between USA and European countries.
  - Some data seem to consistently fall on the wrong side of correlation.
  - Unstable burst pressures for part-throughwall notches that fail unstably immediately after ligament rupture may be rate-dependent.
- Barring direct experimental evidence, rate dependence of unstable burst pressure cannot be ruled out.
  - Burst tests are difficult to conduct at low pressurization rate because bladder and foil tend to get squeezed out through the notch.

# $3\Delta p_{NO}$ Tests - Ligament Rupture or Unstable Burst ?

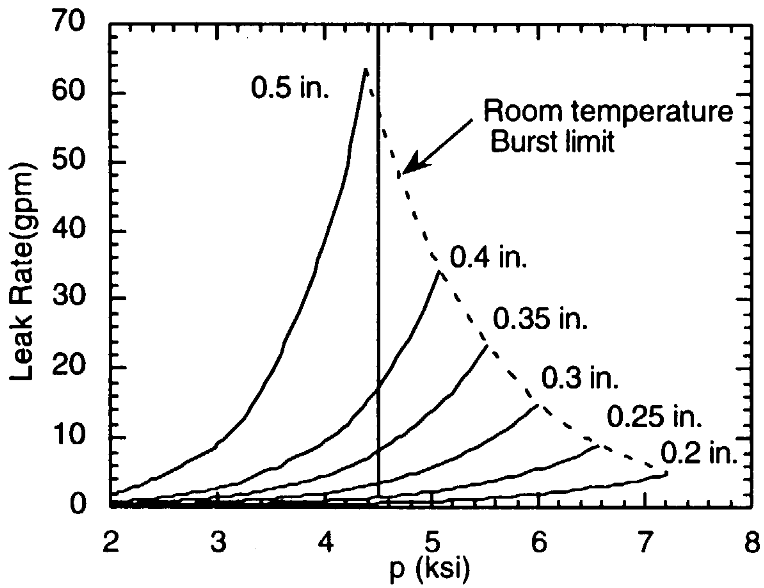
7/8 in. OD, 0.05 in. wall thickness, $S_y$ = 43 ksi, and $S_u$ = 98 ksi.




- Shallow/long cracks are likely to cause unstable burst during $3\Delta p_{NO}$ test
- Deep cracks are likely to see ligament rupture w/o unstable burst unless pump has sufficient flow rate capability.

# Pumping Requirements for $3\Delta p_{NO}$ Tests




7/8" OD, 0.05" wall thickness

Yield = 43 ksi

UTS = 98 ksi

$3\Delta p_{NO}$ = 4.5 ksi

- 12.5 gpm, 8 ksi pump can burst cracks that are at most 0.2-0.25 in. long.
- Throughwall cracks ≥ 0.5 in. cannot meet $3\Delta p_{NO}$=4.5 ksi criterion because of burst and flow rate limitations.
- 0.4 in. crack requires ≥20 gpm capacity pump to demonstrate compliance

# Conclusions - Rate Effects

- Rate dependence of ligament rupture and burst pressures of rectangular notch is about the same as those of Type 14 specimen if specimen-to-specimen variation of notch geometry is taken into account.

- An increase of pressure rate from quasi-static to 2 ksi/s appears to cause a ≈ 10% increase in ligament rupture pressure.

- Tests on specimens with variable notch-tip ligament thickness and with multiple notches with axial and circumferential ligaments are needed to establish rate effects for ligament rupture and unstable burst pressures.

- Rate-effects could be greater for SCC specimens than EDM notches because, unlike rectangular EDM notches, specimens with deep SCC show time-dependent ligament rupture at constant pressure.
  - Incremental material damage due to high stresses in ligaments may introduce time dependent rupture processes

# Conclusions – $3\Delta p_{NO}$ Tests

- Deep cracks are likely to experience ligament rupture w/o burst during $3\Delta p_{NO}$ tests.

<u>7/8 in. OD, 0.05 in. wall thickness, $S_y$ = 43 ksi, and $S_u$ = 98 ksi.</u>

- 0.5 in. long cracks >75% deep cannot meet $3\Delta p_{NO}$=4.5 ksi criterion
- To show compliance of deep cracks ≤0.4 in. long, need 20-gpm pump.

TVA

# In Situ Pressure Test Guidelines Revision 1

Helen Cothron
Tennessee Valley Authority

NRC Workshop
February 27-28, 2001

TVA

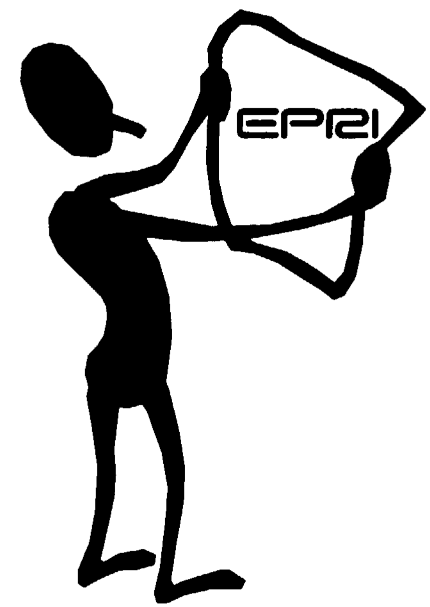
# SG In Situ Pressure Test Guidelines

- Objective
  - Standardize approach to in situ pressure testing
    - Test objectives, procedures, and conditions
    - Screening parameters
    - Test conditions
    - Equipment requirements
  - Supplement the CM/OA process
    - Provide a direct measurement of SG tubing structural and leakage integrity for normal and accident conditions
- Background
  - Revision 1 issued June 1999
  - Ad Hoc committee being formed to write Revision 2
    - Incorporate lessons learned from recent industry events

TVA

# Guidelines Format

- Section 1 - Introduction
- Section 2 - Pressure and Leak Test Objectives
- Section 3 - Compliance Responsibilities
- Section 4 - Screening Parameters/Tube Selection
- Section 5 - Test Procedure
- Section 6 - In-situ Test Conditions
    - Test pressures and adjustments
- Section 7 - Data Analysis
- Section 8 - Industry Database
- Section 9 - Reporting



# Guideline Format (cont)

- Appendices
  - Appendix A - Equipment specification/Tool Qualification
  - Appendix B - Selection Protocol
    - Axial Indication
    - Circumferential Indications
    - Volumetric Indications
    - Mix Mode
    - Pitting
  - Appendix C - Statistical Screening Methodology
  - Appendix D - In Situ Pressure Testing and Leak Rate Adjustments
  - Appendix E - In Situ Testing of Indications Restricted From Burst

TVA

# Pressure Test Objectives

- Demonstrate structural integrity at EOC satisfies performance criteria (e.g. $3\Delta P$, MSLB)
  - Provides absolute measure for CM assessments
  - All appropriate loads should be considered
- Define relationship between NDE data and structural thresholds for OA
  - Provides information to support uncertainty assumptions
  - Requires knowledge of tube material properties and operating conditions of upcoming cycle

# Leak Testing Objectives

- Demonstrate leakage integrity at EOC
  - Per licensing basis and site dose assessments
- Obtain information to support NDE thresholds for accident conditions
- Provide test data to support predictions of MSLB leak rates

TVA

# Selection Protocol

- Guidelines provide screening logic for selecting tubes for in situ pressure testing
  - Screening protocol for pressure and leakage testing
  - Utility is required to develop site-specific screening criteria
  - Sequential logic provided
  - Guidance on sample size as well as expansion criteria
  - Selection of candidate indications is dependent upon the capability of the NDE technique to characterize the flaw
  - Indications tested should ensure that the most limiting tubes are included from both a structural and leakage standpoint

TVA

# NEI Review Board Questions/Resolutions

- Should temperature correction be applied prior to multiplying by the safety factor
  - *Response - Guidelines require increasing the test pressure by the correction first then apply the prescribed margin of safety*

- How should past in situ pressure test results be used to support/bound threshold screening values
  - *Response - In order to use past test results or test results from another plant, material and NDE uncertainties must be appropriately applied in addition to other considerations such as test pressures, flaw morphology, NDE technique, tube geometry, etc.*

TVA

# SGMP Interim Guidance

- SGMP issued interim guidance October 13, 2000, on emergent issues
  - Test all indications above screening criteria
  - A minimum hold time of 2 minutes is required to verify crack stability at conditions of normal operating, limiting accident, and 3dP, regardless of pressurization rate
  - Intermediate hold pressures with the minimum 2-minute hold times at approximately every 500 psig or less, above the limiting accident differential pressure should be used to approach the proof pressure
  - Pressurization rates should be maintained less than 200 psi/sec
  - If leakage develops, insert a sealing bladder prior to raising pressure, if possible, but not before demonstrating leakage integrity at the limiting accident
  - Perform proof test even if screening criteria indicates a need for only leak testing

TVA

# SGMP Lessons Learned Letter

- SGMP issued information letter concerning lessons learned from a review of recent steam generator related issues on September 29, 2000
  - Emphasized the importance of considering NDE uncertainties when selecting tubes for in situ pressure testing
  - Emphasized the need to use a bladder if leakage exceeds the pump capacity
  - Emphasized the use of the NEI Web site for posing questions about interpretation of the guidelines and for reviewing resolution of current issues

TVA

# Summary

- With few exceptions guidance has been successful in test consistency and demonstration of tube integrity
- Industry proactive in dealing with emerging issues and questions
  - NEI Review Board
  - Interim Guidance
  - Lessons Learned letter

# NRC Expectations for Risk-Informed Applications for ARCs, Repair Method, OAs, etc.

Steve Long, (301) 415-1077
Office of Nuclear Reactor Regulation, NRC

Steam Generator Workshop
Bethesda, Maryland
February 27-28, 2000

# NRC Expectations for Risk-Informed Applications for ARCs, Repair Methods, OAs, etc.

IPEs and other PSAs for PWRs generally indicate that SGTR is a major, sometimes the dominant contributor to public health effects.

Current industry PSAs rarely include all the sequences that involve induced tube rupture probability.

The suite of DBAs in USAR Chapter 15 does not include high-pressure core melts in the containment design basis. (Event equivalent to Large LOCA with core damage is included.) So, risk of weak tubes is not fully captured by licensing basis.

NRC's policy and staff guidance is to use risk information to the maximum extent permitted by the state of the art in PRA.

- Licensee submission of risk-informed requests

- Staff use of risk information during review of deterministic requests

# What are the Important Risk Sequences?

Spontaneous Tube Ruptures

(Large variations in human error modeling create large range of results)

Secondary Depressurizations (AKA Main Steam Line Breaks)

(A range of depressurization events may be required, including stuck relief valves, small pipe breaks, MSIV failures and large pipe breaks)

Primary Over-pressurizations

ATWS is only known initiator (except when tubes are near spontaneous rupture)

Severe Accidents

Pressure induced ruptures if secondary depressurizes before RCS

Thermally-induced ruptures if secondary is depressurized during occurrence of core damage

# Some Thoughts About Modeling Thermally-Induced Ruptures

Cutting of adjacent tubes by gas/particulate jets from cracked tubes has recently been shown to have little effect on accident progression

However, leakage through tube cracks may affect mixing in the steam generator inlet plenum for U-tube SGs and flow to tubes in OT generators, which increases tube temperatures in a manner that cannot be adequately modeled with current knowledge and techniques. *So, SG tube leakage under accident conditions is a risk concern.*

Depressurization of the RCS through the accumulator discharge phase before core oxidation occurs has been shown to be effective in preventing creep failure of weakened tubes. *The crux is to have a means of depressurization that is reliable under the conditions that are causing the high-pressure core damage event.*

# Risk-informed Submittal Contents

RG 1.174 describes 5 principles, *plus* need to consider uncertainty

1. meet current regulations (unless requesting exemption or rule change)

2. preserve defense-in-depth

3. maintain sufficient safety margins

4. keep risk increases small ($\Delta$CDF and $\Delta$LERF guidance, sensitive to total CDF and LERF)
5. monitor risk impact with performance measurements

*plus*

evaluate and consider uncertainties in analysis, including program for monitoring, feedback, and corrective action to address uncertain parameters

Risk should be addressed in an *integrated manner* as part of an overall risk management approach

# Which Requests Should be Risk-Informed?

Changes that increase allowable accident leakage above 1 gpm. (Although ARCs for degradation in areas that are closely confined, such as tube sheets, may have ARC-specific leakage values calculated as if the degradation is in the free-span, this is not normally a risk-significant issue, unless actual leakage is expected to exceed 1 gpm.)

Changes in materials that would result in different behavior under severe accident conditions.

Exemptions from normal pressure capability requirements

Continued operation when operational assessments that do not meet normal deterministic criteria for continued operation without mid-cycle inspections

# Do's and Don'ts

Do address LERF as well as CDF

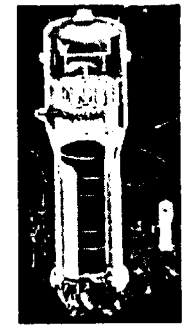
Do address PRA level 2 (accident progression) issues with respect to SG tube integrity. (That is, for accident sequences in which *core damage* is *not* dependent on tube failure, consider whether challenges to tube integrity *can* occur that would cause containment bypass.)

Don't use arbitrary definitions of LERF to exclude accidents with core damage and containment bypass from the LERF category. (If radiation releases are not of the same order as the core damage accidents with successful containment, count it as LERF, not as a contained accident.)

Don't use flaw POD estimates that are inconsistent with plant experience as the basis for risk estimates.

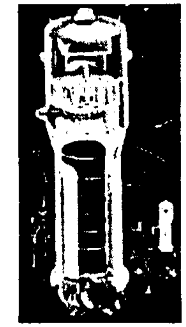
Do address all potentially significant physical factors that can be involved in estimating a probability. If some of those factors are not important to the quantification of the risk for the current application, state the reason. (This allows for identification of parameters that may need to be included as monitored conditions, such as flaws not extending beyond the confines of the tube support plates.)

EPRI



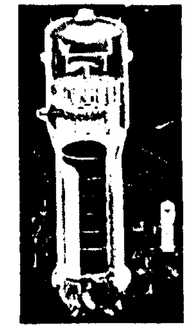
# Primary to Secondary Leak Guidelines, Revision 2

Forrest Hundley
Southern Nuclear Operating Company
February 28, 2001



# Primary to Secondary Leak Guidelines

- Background
  - Original recommendations (Rev. 0) dated May 1995
  - Updated (Rev. 1) in November 1997
  - Revision 2 published in May 2000
  - Since Revision 0 Indian Point-2 is the only large tube leakage event that has occurred
    - Integrity Analysis
    - Improved inspection methods and NDE interpretation
    - Improved Water Chemistry Programs
    - SG Pri-to-Sec leakage guidelines provided defense-in-depth to insure leakage has a low probability of escalating to a tube rupture

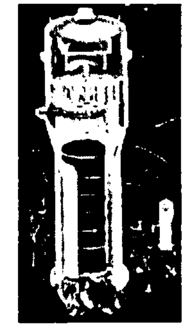


# Primary to Secondary Leak Guidelines

- Objective
  - A technically justified program for use by utilities to develop a station specific Pri-to-Sec leakage program
  - Reflect recent field experience
  - Reflect the issuance of NEI 97-06
  - Insure guidelines help utilities to manage small leaks
  - Insure the propagation of flaws to tube rupture is minimized under normal and faulted conditions

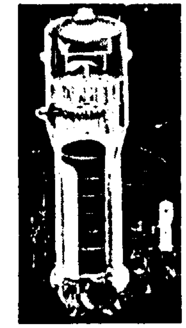
EPRI

# Guidelines (Rev. 2) Preparation



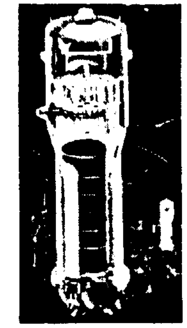
- Ad Hoc committee formed representing
  - 18 Utilities
  - INPO
  - 3 NSSS Vendors
- Four meetings held and draft produced in 2000
- Approval Process
  - Ad-Hoc committee
  - SGMP TSS
  - SGMP IIG
  - SGMP Executive committee

EPRI



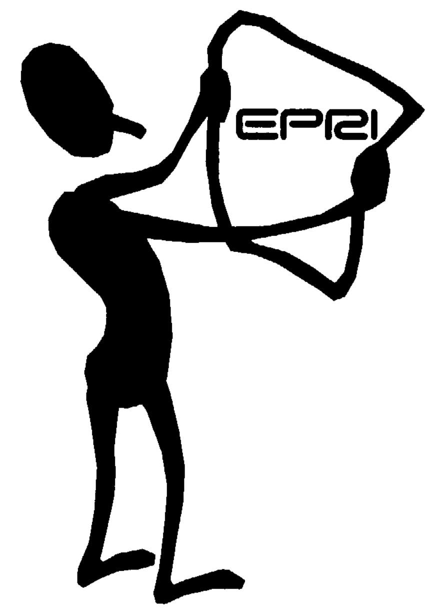
# Guidelines (Rev. 2) Implementation

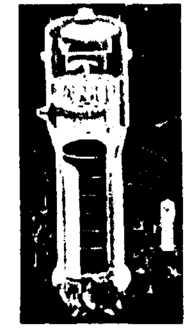
- Guidelines transmitted to the utilities on April 14, 2000 via cover letter signed by the SGMP Executive Chairman
  - Licensees shall implement guidelines by October 14, 2000
  - If licensees had a refueling outage within the 6 month implementation period, licensees may delay implementation by 3 months



# Guidelines Format

- Section 1 - Introduction and Management Responsibilities
- Section 2 - Technical Bases for Pri-to-Sec Leakage Limits
- Section 3 - Operating G/Ls for Pri-to-Sec Leakage
- Section 4 - Continuous Radiation Monitoring
- Section 5 - Leak Rate Calculation

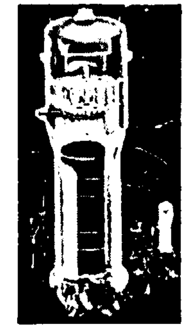




# Guideline Format (cont)

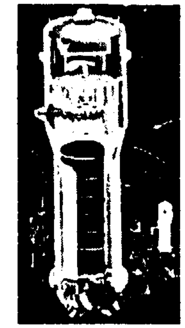
- Appendices
  - Appendix A - Data Interpretation
  - Appendix B - Condenser Off Gas corrections
  - Appendix C - Leak Rate Calculation Methodology for the blowdown analysis
  - Appendix D - Pri-to-Sec Leakage Quantification during non-operating conditions
  - Appendix E - Examples of computer calculated Pri-to-Sec leak rate for condenser air ejector monitor

EPRI



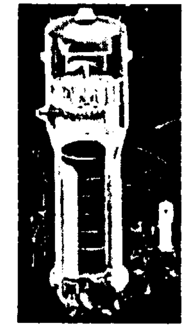
# Key Changes to Revision 2

- Added detailed technical bases
- Increase emphasis on use of inline monitors verse grab samples
- Changed limits based on strong technical bases including new field data
  - Lowered limit for sustained leakage to 75gpd
  - Retained limit of 150 gpd for spikes
  - Lowered limit for rate of change to 30 gpd/hr and increased time to shutdown to 3 hours
- New Action Level when no on-line quantitative monitors ($\leq$ 30 gpd) are operable



# IP2 Implications Relative to Rev 2

- Very low leak rate (<4 gpd) detected over the last year
- No difference between Rev 1 and Rev 2 for leakage at this level
- Guidance (in both revisions) is as follows:
  - **"Increased Monitoring" is triggered at 5 gpd**
  - **Below 5 gpd "Normal Operation" no specific actions are recommended**
- Grab samples should quantify leakage at 5 gpd
- Rad monitors should detect a 30 gpd leak



# Summary

- Provides margin to the current Tech Spec leakage limit
- Leakage monitoring is not a surrogate for structural integrity
- Provides utilities with guidance:
  - To insure the propagation of flaws to tube rupture is minimized
  - To develop a technically justified Pri-to-Sec leakage program
  - To manage small leaks
  - To insure on-line leakage monitoring is both reliable, dependable and provides accurate measurements